MOTOR BRAKE DEVICE FOR A TURBOCHARGED INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The invention concerns a motor brake device for a turbocharged internal combustion engine, a process for operating the motor brake device as well as an internal combustion engine with such a motor brake device.

Description of the Related Art

[0002] In the area of turbocharged internal combustion engines it is known that in addition to the motor brake of the internal combustion engine the turbocharger may also be provided with its own brake assist device. In a typical manner of operation such a brake assist device always brings about a transformation of the turbocharger from a power output or drive device to a brake device when a brake assist process is necessary. This generally occurs by modification of the exhaust and/or suction side control of the turbocharger in such a manner that a movement of the cylinder pistons is changed from a low as possible power output loss to a large as possible power output loss and namely then when the braking of the turbocharger occurs. Such an absorption of power is based on the principle of an air compressor, that is, the cylinder pistons perform work on the air contained within the cylinders of the motor when braking is necessary.

[0003] Here there exist two fundamentally different concepts by which a brake assist for the internal combustion engine can be realized with the aid of the turbocharger:

[0004] According to a first process it is attempted, by reducing the effective cross-section of the exhaust gas side, to increase the pressure in the exhaust pipe, in order to thereby create a so-called counter pressure or back pressure, which is transmitted to the gas in the cylinder volume of the internal combustion engine. On the basis of the higher

pressure in the cylinder internal space the cylinder pistons must perform a greater amount of work, which leads to braking. In practice this is carried about in various ways:

[0005] In DE 195 43 190 A1 a brake assist device for a charged internal combustion engine is described, which includes an exhaust gas turbocharger with variably adjustable turbine geometry via adjustable guide vanes. The channeling means include guide vanes, which can be so adjusted with the aid of an adjusting mechanism, that the effective, that is, the useful turbine cross-section of the turbine geometry, is changed. Thereby, depending upon operating condition of the internal combustion engine, various elevated exhaust gas pressures can be realized in the segment between the cylinders and the turbocharger, whereby the output of the turbine and the output of the compressor can be adjusted according to need.

[0006] In order to cause a motor braking during operation of the internal combustion engine, this array of guide vanes is brought into a constriction orientation in such a manner that the effective turbine cross-section is significantly reduced. In a guide vane assembly segment between the cylinders and the turbine a high exhaust gas pressure builds up with the consequence that exhaust gas flows with high velocity through the channels between the guide vanes of the turbine and impact the turbine wheel with a high impulse. The turbine output is transmitted to the compressor, whereupon the charge air supply to the motor is placed under elevated charge pressure by the compressor. Thereby the cylinder on the charge air side is acted upon with increased charge air, at the exhaust gas side there is an elevated exhaust gas pressure between the cylinder outlet and the turbocharger, which counter acts the output of the air compressed in the cylinders by opened brake valves in the exhaust pipe segment. In the

motor braking operation the piston must perform increased compression work against the high overpressure in the exhaust line, whereby depending upon the positioning of the guide vanes a more or less strong braking effect is achieved.

[0007] Supplementally or alternatively thereto turbines provided with guide vanes can also have a flap valve, which is provided in the exhaust gas line downstream of the turbine. This flap can be pivoted perpendicular or substantially perpendicular to the exhaust gas line in the braking operation of the motor brake device and reduces thereby the effective cross-section in the exhaust gas line, whereby upstream in the direction of the cylinder outlet the pressure in the exhaust gas line increases and therewith a braking effect is achieved. A turbocharger with such a flap is described for example in DE 40 24 572.

[0008] According to a second concept an exhaust gas return line can be provided for elevating the motor brake effectiveness, which is activated during the motor braking operation. Therein exhaust gas out of the exhaust pipe which during the motor braking operation includes various amounts of uncombusted exhaust gas air and which due to compression in the cylinders has an elevated temperature level, is supplied again to the cylinders of the internal combustion engine.

[0009] In DE 198 53 127 A1 such a motor brake device with exhaust gas recirculation is described. There the exhaust gas is branched off prior to the turbocharger, is directed in the direction of the cylinder inlets, and is mixed together with the combustion air compressed in the compressor of the turbocharger and supplied to the cylinders. A back-flow valve is provided in the line for exhaust gas recirculation. This back flow valve is necessary here in order to balance out

pressure differentials between the exhaust gas line and the charge air line.

[00010] All of the above mentioned brake assist devices of a turbocharged internal combustion engine are however designed only for so-called single stage turbochargers. Modern turbochargers can however have a two stage charge system.

[00011] An internal combustion engine equipped with such a two-stage charge system is described for example in German patent publication DE 198 37 978 A1 and DE 195 14 572 A1. In such a two-stage charged internal combustion engine the set of turbochargers respectively includes one high-pressure stage and one low-pressure stage arranged in sequence to each other. The exhaust gas leaving the motor first flows through the high-pressure turbine and subsequently the low-pressure turbine. In the same manner the charge air for supplying the cylinders is first compressed by a low-pressure compressor and subsequently by a high-pressure compressor and supplied to the charge air side of the internal combustion engine, in certain cases following cooling of the charge air in a heat exchanger. In a typical mode of operation the turbocharger during low RPM of the internal combustion engine is operated in two stages. As the RPM increases operation can be switched to the single low pressure compressor, wherein for example by means of an exhaust gas sided bypass line the high pressure turbine can be completely or at least partially bridged over or bypassed. In this case the high-pressure compressor could also be completely bypassed via a pipe switch or valve provided in the charge air side.

[00012] In such a two-stage turbocharger the turbines and compressors respectively arranged in series are designed for different charge pressures. In practice this has the consequence, that very large constructive expenditure is

necessary for realizing the above-mentioned brake assist device. In order for example to obtain one optimal brake assist module for each of the respective different modes of operation of the two-stage turbocharger, a large number of pipe switches indispensable in order respectively to achieve the desired pressures in the exhaust pipes and charge air lines. Such brake devices are thus very expensive in their manufacture, wherein however the increased expenditure does not bring about an improvement in braking quality. In particular in the case of very small turbochargers, which are employed primarily in internal combustion engines with very small engine compartments, such a brake assist device has not been provided in satisfactory manner until now.

SUMMARY OF THE INVENTION

[00013] The present invention is thus concerned with the task of providing a improved braking device for a two-stage turbocharger of an internal combustion engine.

[00014] In accordance with the invention this task is solved by an internal combustion engine with the characteristics of patent claim 1. Further this task is solved by a process for operating the brake device with the characteristics of patent claim 18 as well as an internal combustion engine with the characteristics of patent claim 24.

[00015] In accordance therewith there is provided:

- A motor brake device for a turbocharged internal combustion engine, with an at least two-stage charge system, which includes at least one high pressure stage as well as at least one low pressure stage downstream in the direction of the exhaust of the high-pressure stage and/or the low-pressure stage, and upstream in the direction of the charge air side, with at least one

exhaust pipe provided downstream of the internal combustion engine and connected with the outlet channels of the internal combustion engine, with at least one closing or blocking body, which is provided in the exhaust pipe downstream of the low-pressure stage relative to the direction of flow of the exhaust gas, wherein the closing body is of such a design, that the exhaust gas flow-through, and the pressure in the exhaust line dependent thereon, is changeable in such a manner that thereby the motor braking power is variably adjustable as needed (patent claim 1).

- A process for operating a motor brake device for a turbocharged internal combustion engine, which by means of a control device adjusts the value of a first pressure in the exhaust pipe upstream of the high-pressure turbine depending upon the braking mode (patent claim 18).

- An internal combustion engine with a motor block, which includes at least one cylinder and includes at least one charge air inlet and at least one exhaust gas outlet, with a charge system capable of functioning as a braking device (patent claim 24).

[00016] Advantageous embodiments and further developments of the invention can be seen in the dependent claims as well as the figures and associated text.

BRIEF DESCRIPTION OF THE DRAWINGS

[00017] The invention is in the following described in greater detail on the basis of the embodiments shown in the figures. There is shown:

Fig. 1 a first embodiment of an inventive two-stage charged internal combustion engine with regulating or

control valve in the exhaust gas manifold in schematic representation;

Fig. 2 a second illustrative embodiment of an inventive two-stage charged internal combustion engine according to Fig. 1 with incorporated exhaust gas recirculation line;

Fig. 3 a third embodiment of an inventive two-stage charged internal combustion engine according to Fig. 1 with variable turbine geometry;

Fig. 4 a fourth embodiment of an inventive two-stage charged internal combustion engine according to Fig. 1 with a high pressure turbine in the form of a split stream or dual flow turbine;

Fig. 5 a fifth embodiment of an inventive two-stage charged internal combustion engine according to Fig. 1, in which the closing body is provided between the high-pressure stage and the low-pressure stage;

Fig. 6 a sixth particularly preferred embodiment of an inventive two-stage charged internal combustion engine in schematic representation.

DETAILED DESCRIPTION OF THE INVENTION

[00018] In all figures the same or, as the case may be, functionally equivalent elements - insofar as not otherwise indicated - are provided with the same reference numbers. In all figures the direction of the exhaust gas flow as well as the charge air flow are respectively shown by arrows in the appropriate lines.

[00019] Fig. 1 shows in a schematic representation a first embodiment of an inventive braking device.

[00020] In Fig. 1 an internal combustion engine is indicated with reference number **1**. In the illustrated example the internal combustion engine **1** is in the form of a straight six-cylinder diesel internal combustion engine and thus comprises six cylinders **2** arranged in a row. The internal combustion engine **1** includes a fresh air side **3** and exhaust side **4**, wherein the inlets **7** on the fresh air side **3** are connected with a charge air collector **5** and the outlets **8** of the internal combustion engine **1** on the exhaust gas side **4** are connected with two exhaust gas collectors or manifolds **6**.

[00021] The internal combustion engine **1** is charged via a turbocharger indicated with reference number **10**. In the illustrated embodiment the turbocharger **10** is a two-stage turbocharger. Such a two-stage turbocharger **10** includes a high-pressure stage **11** and a low-pressure stage **12**. The high-pressure stage **11** is comprised of a high-pressure turbine **13** and a high-pressure compressor **14**, which are rigidly connected with each other via a common shaft **15**. The low-pressure stage **12** is comprised of a low-pressure turbine **16** and a low-pressure compressor **17**, which likewise are connected with each via a common shaft **18**. The high-pressure stage **11** is upstream of the low-pressure stage **12**.

[00022] The diameter of the turbine wheel of the low-pressure turbine **16** is in the present case greater than that of the high-pressure turbine **13**, wherein the turbine wheel diameter relationship between low-pressure and high-pressure turbines typically but not necessarily is in the range of 1.2 - 1.8. In the same manner the compressor wheel of the high-

pressure compressor **14** has a smaller diameter than the compressor wheel of the low-pressure compressor **17**.

[00023] The exhaust line **6** is connected in the upstream direction with exhaust gas lines **20, 21, 22**, via which the exhaust gas can be channel out of the cylinders **2** of the internal combustion engine **1**. In the same manner charge air lines **23, 24, 25** are provided, which are connected upstream with the charge air collector **5**. Charge air can be supplied to the cylinders **2** of the internal combustion engine via the charge air lines **23, 24, 25** and the compressor **14, 17**.

[00024] The two turbines **13, 16** are arranged sequentially, wherein the high-pressure turbine **13** is connected with the low-pressure turbine **16** via the exhaust gas line **21** and upstream of the low-pressure turbine **16** with respect to the direction of flow of the exhaust gas. In the same manner the low-pressure compressor **17** and the high-pressure compressor **14** are arranged sequentially and connected with each other via a charge air line **24**, wherein the low-pressure compressor **17** is provided upstream of the high-pressure compressor **14** with respect to the direction of flow of the charge air.

[00025] Further, a first charge air cooler **26** is provided, which is located in the charge air line **24** between the two compressors **14, 17**. A second charge air cooler **27** is provided in the charge air line **25** between the high-pressure compressor **14** and inlets **17** of the internal combustion engine **1**. If necessary one or, in extreme cases, both charge air coolers **26, 27** can be omitted.

[00026] In accordance with the invention a variable closing device **30** is provided, which is shown here in the form of a controllable or adjustable valve. The closing device **30** can

however be a braking flap, a throttle flap, pusher or the like. The valve **30** is adjustable Via an adjusting element **31** connected with the control valve **30**. The closing device **30** can be made controllable or adjustable via a control or adjusting device not shown in Fig. 1. The function of such a control or adjusting device is described in the following in greater detail on the basis of Fig. 6.

[00027] In distinction to Fig. 1, the device according to Fig. 6 additionally includes an exhaust gas recirculation line **32**. The exhaust gas recirculation line **32** branches from the exhaust line **20**, which comes out of the exhaust collecting line **6**, and branches in the charge air line **25**, which connects the high-pressure compressor **14** with the charge air collector line **5**. The particular advantage of the arrangement shown in Fig. 2 is comprised therein that on the basis of the pressure relationship in the exhaust lines **6, 20** as well as the charge air lines **5, 25** no return valve or one-way valve need be provided and beyond this, as will be described in the following, it is not even necessary.

[00028] In distinction to the arrangement in Fig. 1 the turbocharged internal combustion engine **1** according to Fig. 3 includes a turbocharger **10**, which includes a high-pressure turbine **13** with variable turbine geometry (VTG). The functionality of a variable turbine geometry is indicated in all the figures with an arrow.

[00029] In distinction to the arrangement according to Fig. 1, the turbocharged internal combustion engine according to Fig. 4 includes a high-pressure turbine **13** with a dual volute. This twin volute high-pressure turbine **13** is comprised of two parallel turbine wheels **13A, 13B** which are connected with each other - typically rigidly. Typically, however not

necessarily, these two turbine wheels **13A, 13B** can have the same flow-through cross section of the turbine channels.

[00030] In contrast to the arrangement in Fig. 1, in the fifth illustrated embodiment shown in Fig. 5 a closing device **30** is provided between the high-pressure stage and low-pressure stage **11, 12**. Since the brake flap **30** acts here directly upon the high-pressure stage, this arrangement has been found, in contrast to the arrangement shown in Fig. 1, as having a higher precision and speed of control of the high-pressure stage **11**.

[00031] For the optimal adaptation of the two-stage turbocharger **10** to the operating condition of the internal combustion engine **1**, there is provided in each channel **13A, 13B** of the two-staged twin volute pressure turbine **13** a bypass line in preferably symmetric connection. These respectively branch from the separate pipes **20A, 20B** which are exhaust gas connecting pipes, circumvent the dual volute turbine **13** and interface for the same impact on the single volute low-pressure turbine **16** in the common line **21**. Each bypass line **33A, 33B** is provided with a pipe switch **34A, 34B** downstream of the branch, for example in the form of a control valve. These pipe switchs **34A, 34B** are advantageously integrated into the exhaust gas connecting pipe or manifold or in the housing of the high-pressure turbine **13** and can be sliders, valves, flaps, restrictors, dampers or the like and for example can be controlled individually or collectively via a programmed unit, for example a CPU.

[00032] Preferably, however not necessarily, the turbine wheels **13A, 13B** of the twin volute or twin flow high-pressure turbine **13** are operated synchronized.

[00033] Fig. 6 shows in a schematic representation a sixth, particularly preferred embodiment of an inventive two-stage charged internal combustion engine. The preferred arrangement in Fig. 6 is comprised essentially of a combination of the various components of an internal combustion engine **1** according to Figs. 1-4. The internal combustion engine **1** is here equipped with a control valve **30**, an exhaust gas return line **32**, bypass lines **33A, 33B** with pipe switches **34A, 34B** provided thereon. In addition the high-pressure stage **11** includes a twin volute high-pressure turbine **13**, which in the high-pressure turbines **13A, 13B** respectively have a variable turbine geometry.

[00034] At this point it can be noted, that the low-pressure turbine **12** can of course also be in the form of a twin flow or dual volute turbine. Beyond this, additionally or alternatively, the low-pressure turbine **12** can also have variable turbine geometry.

[00035] Fig. 6 additionally shows a control device **40**. The control device **40** includes data inputs **41** and data outputs **42**. Via the data inputs **41** data can be input such as for example analog measurement values such as for example a temperature or the pressure of the exhaust gas or the charge air, the RPM of the motor, etc., or digital data can be input. Depending upon this data and a preprogrammed program of the control device **40** this produces controlled signals, which can be read at the outputs **42**, of the control devices **40**.

[00036] The data outputs **42** are connected via a plurality of control lines **43 - 46** with the control valves **34A, 34B**, with the twin flow pressure turbine **13**, with the low-pressure turbine **12** as well as with the control element **31** of the control valve **30**.

[00037] Further a restrictor **35** is provided, which is located in the exhaust gas recirculation line **32**. This is typically likewise adjusted or activated via the control device **40**.

[00038] In addition it is possible to provide a further exhaust gas recirculation line, not shown in Fig. 6, in which a portion of the returned exhaust gas is supplied to any other point of the charge air side. Typically, however not necessarily, up to approximately 50% of the exhaust gas is returned back to the internal combustion engine **10** via the charge air side **3**.

[00039] The manner of operation of a turbocharged internal combustion engine **1** is generally known and is described in detail in the references mentioned in the above introduction, so that in the following this need only be described briefly:

[00040] The six-cylinder diesel internal combustion engine **1** is charged by a two-stage turbocharger **10**. For this, a twin high-pressure stage **11** is provided upstream of a single low-pressure stage **12**. Charge air is compressed by the compressor **14** or as the case may be **17** driven by the twin flow turbines **13A, 13B** and the low-pressure turbine **16**, cooled in the two charge air coolers **26, 27**, mixed in a particular proportion (≥ 0) with exhaust gas from the exhaust gas recirculation line **32** and supplied to the charge air side **3** of the internal combustion engine **1**.

[00041] For controlling the pipe switch **30, 33A, 33B**, the closing body as well as the turbines **13, 16** which in their geometry are variable depending upon the operating values A1 - An these are connected to an electronic motor control **40**, for

example a CPU, which ensures an optimal distribution of the exhaust gas flow for operation. By the possible adjustment of various bypass rates, flow through rates and turbine configurations one obtains in advantageous manner a supplemental degree of freedom for dividing or distributing the total exhaust gas amount, which is of particular significance for the brake assist operation of the turbocharger **10**.

[00042] In the following the manner of operation of a turbocharger **10** configured as brake assist device in accordance with the invention will be described in greater detail with reference to Fig. 6:

[00043] In the case of closed bypass valves **34A, 34B** and a controllable exhaust brake flap **30** an elevated motor brake power is achievable, which is made possible by an elevated exhaust gas pressure due to the small high pressure stage **11**. In the case of use of various sizes of channels **13A, 13B** of the high-pressure twin turbine **13** and a controlled regulation of the respective bypass valves **34A, 34B** the appropriate rotational speed range for braking operation can be optimally met. The various channel diameters of the two high-pressure turbines **13A, 13B** can be achieved on the basis of their variable turbine geometry by suitable control of the motor control **40**. Thereby a differential distribution of the exhaust gas flow to the high and low-pressure stages **11, 12** can be divided or distributed.

[00044] This exhaust gas mass flow can be influenced as follows:

1. In the case of suitable adjustment of the control valve **30**, the effective cross-section of the exhaust gas line **22** can be targetedly adjusted.

2. The high-pressure turbines **13A, 13B** and preferably also the low-pressure turbine **16** exhibit a variable turbine geometry. In the case of suitable control the effective channel cross-section of the respective turbines can be selected to be greater or smaller.

3. Via the bypass valves **34A, 34B** it can be adjusted which proportion of the exhaust gas flows through the high-pressure turbines **13A, 13B** and which proportion bridges over or bypasses the high-pressure turbines **13A, 13B**.

[00045] By the mentioned measures, that is, by suitable control and/or regulation of the just mentioned elements, there can in defined manner a pressure **P1** on the exhaust gas in the exhaust gas lines **6, 20** and therewith also in the cylinders **2** be adjusted. In a particularly preferred embodiment, in particular in the case of presence of an exhaust gas recirculation line **32** according to Fig. 6, there can therewith be ensured, that the exhaust gas side pressure **P1** in the exhaust gas line **20** is always greater than the charge air side pressure **P2** in the charge air line **25**. Since therewith a pressure drop continuously exists between the exhaust gas side and charge air side area of the exhaust gas return line **32**, here advantageously there is no need for a return block valve or one-way valve in the exhaust gas recirculation line **32**.

[00046] In a further advantageous embodiment, it can be ensured that the pressure **P1** on the exhaust gas side is maintained constant.

[00047] In addition, by the different sizes of the channels **13A, 13B** of the twin flow turbine **13** with separate control of the bypass valves **34A, 34B** an optimal dosing of the

recirculated exhaust gas amount (EGR-amount) to the respective desired operating condition is made possible. A supplemental EGR-valve, which is always necessary for example in the above-described state of the art, is here not necessary.

[00048] In Fig. 6 nevertheless a throttle or restrictor **35** is provided in the exhaust gas recirculation line **32**, via which the exhaust gas mass flow can be supplementally dosed via the return gas line **32** with suitable control. Thereby the motor characteristics can be targetedly influenced, in that for example the motor operation values with respect to the harmful emissions (N_{ox}, CO, CO_2) and with respect to the fuel consumption can be substantially optimally adjusted. A particular advantage of this inventive exhaust gas recirculation is comprised therein, that the exhaust gas flow is already achieved solely by the pressure drop of pressure gradient between the exhaust gas side and charge air side. Thus is it completely sufficient, to provide merely a flow through restrictor in the exhaust gas recirculation line **32**, wherein however this also - as already mentioned above - can be omitted without noticeable compromise of the function of the brake assist device.

[00049] Of course, the invention is not exclusively limited to the two-stage turbocharger, but rather can be practiced with a three or more stage turbocharger.

[00050] The two turbocharger stages are, in the present embodiment, preferably components of a single turbocharger and are thus integrated into one housing of the turbocharger. However this advantageous integration of two turbocharger stages into a single turbocharger is not absolutely necessary, but rather the same function can be achieved by two separate, sequentially arranged turbochargers, although this arrangement

is less preferred on the basis of the complexity of assembly and installing and the higher costs.

[00051] Finally, the invention is not exclusively limited to diesel internal combustion engines with a straight six-cylinder arrangement but rather can also be applied to various internal combustion engines with a varied number of cylinders.

[00052] In the present illustrated embodiment the low-pressure stage exhibits a greater diameter than the high-pressures stage with respect to the turbine wheels. However, this is not absolutely necessary, but rather it would also be conceivable, that the two turbine stages have the same turbine wheel diameter or as the case may be the high-pressure stage exhibits the higher wheel diameter.

[00053] In the present illustrated embodiment the control of the closing bodies (valves, flaps, pipe switches, etc.) as well as the turbine geometry was described on the basis of a motor control. Of course, some or all of these elements can also be controlled in other manners or using an installed control device be adapted to the desired operating conditions. The control or actuation of the closing bodies or, as the case may be, turbine geometry, can occur electrically, pneumatically, hydraulically or mechanically.

[00054] In summary it can be concluded, that by using the two-stage turbocharger as described a complete departure from previously known solutions a targeted adjustable exhaust gas side pressure, in particular a constant pressure, can be adjusted or controlled in a very simple manner, without a complex and expensive solution according to the state of the art being necessary.

[00055] The present invention was described on the basis of the above in such a manner that the principle of the invention and its practical application is described in detail, however the same invention can be realized in various other embodiments by suitable modifications.

Reference Number List

1	internal combustion engine
2	cylinder
3	charge air side
4	exhaust gas side
5	charge air collection line
6	exhaust gas collection line
7	inlet
8	outlet
10	turbocharger
11	high-pressure stage
12	low-pressure stage
13	high-pressure turbine
13A, 13B	turbine wheels of the split flow high-pressure turbine, channel
14	high-pressure compressor
15	shaft
16	low-pressure turbine
17	low-pressure compressor
18	shaft
20, 20A, 20B	exhaust gas line
21, 22	exhaust gas line
23, 24, 25	charge air line
26, 27	charge air cooler
30	valve
31	adjusting element
32	exhaust gas pressure line
33A, 33B	bypass line
34A, 34B	bypass valve, pipe switch
35	flow through restrictor

40	control device, motor control
41	data input
42	data output
43 - 46	control line
P1	exhaust gas side pressure
P2	charge air side pressure